1984-09

The development of a performance and mission planning program for the A-7E aircraft.

Hill, Roger Dale

Monterey, California. Naval Postgraduate School

http://hdl.handle.net/10945/19263

NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

THE DEVELOPMENT OF A PERFORMANCE
AND MISSION PLANNING PROGRAM FOR THE A-7E AIRCRAFT

by

Roger Dale Hill

September 1984

Thesis Advisor: D. M. Layton

Approved for public release; distribution unlimited.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
The Development of a Performance and Mission Planning Program for the A-7E Aircraft.

5. TYPE OF REPORT & PERIOD COVERED
Master's Thesis
September 1984

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Roger Dale Hill

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Naval Postgraduate School
Monterey, California 93943

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Naval Postgraduate School
Monterey, California 93943

12. REPORT DATE
September 1984

13. NUMBER OF PAGES
53

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
NATOPS
MISSION PLANNING
A-7E
COMPUTERIZED AIRCRAFT DATA

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
In this thesis, drag and performance data from the A-7E Naval Air Training and Operating Procedures Standardization Manual (NATOPS) were reduced to a series of analytical expressions and implemented in a mission planning program. The program was designed to be compatible with desk-top calculators (64K memory) of the type used in aircraft carrier Strike Operations Centers and to be interactive, so that air wing and operations personnel may use it regularly for mission planning.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Block 20 continued

All or part of 15 NATOPS performance charts were reduced using math modeling techniques which included curve-fitting and cross-plotting coefficients. Program implementation was demonstrated on an IBM 3033 using a Waterloo BASIC Compiler, and the program was checked for accuracy and operational suitability by a sample group of Navy attack pilots.

The Development of a Performance and Mission Planning Program for the A-7E Aircraft

by

Roger Dale Hill
Commander, United States Navy
B.S., United States Naval Academy, 1970

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
September 1984

ABSTRACT

In this thesis, drag and performance data from the A-7E Naval Air Training and Operating Procedures Standardization Manual (NATOPS) were reduced to a series of analytical expressions and implemented in a mission planning program. The program was designed to be compatible with desk-top calculators (64K memory) of the type used in aircraft carrier Strike Operations Centers and to be interactive, so that air wing and operations personnel may use it regularly for mission planning.

All or part of 15 NATOPS performance charts were reduced using math modeling techniques which included curve-fitting and cross-plotting coefficients. Program implementation was demonstrated on an IBM 3033 using a Waterloo BASIC compiler, and the program was checked for accuracy and operational suitability by a sample group of Navy attack pilots.

TABLE OF CONTENTS

I. INTRODUCTION ---------- 7

A. BACKGROUND ---------- 7

B. GOALS ---------- 10

II. PROBLEM APPROACH ---------- 11

A. PROGRAM DESIGN ---------- 11

B. RESTRICTIONS ---------- 12

III: SOLUTION ---------- 13

A. DRAG COMPUTATIONS ---------- 13

1. Basic Store Drag ---------- 13

2. Interference Drag ---------- 14

3. Trim Drag ---------- 14

B. NUMERIC REDUCTION OF GRAPHS ---------- 15

C. PROGRAM DESCRIPTION ---------- 19

1. Data Input ---------- 19

2. Total Drag Subroutine ---------- 19

3. Takeoff And Acceleration Segment ---------- 19

4. Mission Menu ---------- 20

D. PROGRAM ANOMALIES ---------- 22

IV. RESULTS ---------- 23

V. CONCLUSIONS AND RECOMMENDATIONS ---------- 25

APPENDIX A: Least Squares Fit Approximation ---------- 26

APPENDIX B: Performance Chart Reduction ---------- 29

APPENDIX C: A-7E NATOPS Drag Data Charts ---------- 34

APPENDIX D: A-7E Mission Planning Program ---------------------- 38

LIST OF REFERENCES --- 52

INITIAL DISTRIBUTION LIST -------------------------------------- 53

I. INTRODUCTION

A. BACKGROUND

Improvements in satellite-aided detection and over-the-horizon targeting techniques have allowed the Soviets to develop an effective long range strike capability against U. S. Navy carrier battle groups. To counter this development, the U. S. Navy has shifted the emphasis of carrier operations to the projection of sea power to ranges limited only by the endurance of its strike aircraft. Carrier airwings now routinely practice long range strikes to targets at ranges of 800-1000 nautical miles from the battle group. These long range missions usually include many aircraft types with different mission weapon loads and fuel states. One of the most difficult tasks the airwing strike planner encounters is the determination of range and performance characteristics of specific aircraft types. Each aircraft in the strike group may have a different weapons and fuel configuration and therefore each will have a different maximum range, speed, etc. In order to determine the maximum range of the strike group and the requirement for air-refueling assets, the strike planner must be able to accurately forecast the performance and fuel usage of each aircraft in the strike group. This task is ostensibly accomplished by the planner manually extracting fuel consumption and performance data for each aircraft from

the appropriate Naval Air Training and Operating Standardization (NATOPS) Flight Manual. This technique is laborious, time-consuming, error-prone, and too difficult to accomplish for every strike. This technique is also complicated by the number of variables involved, such as varying drag counts for changing altitude or airspeed, changes in aircraft gross weight, deviation from standard day conditions, and configuration changes during the mission. Consequently, few planners actually use this technique to plan specific missions. Instead, they rely on range and performance estimates from experienced pilots. When unusual profiles or unfamiliar weapons loads are involved, these estimates are usually in error, but the degree of error is not generally apparent until the mission is actually executed. The estimation technique is also not a valid predictor of maximum capability. Most planners project maximum ranges on the conservative side as it is better to have a fuel "cushion" than to expose the mission to failure due to higher than expected fuel consumption. The result is a limitation to the possible options available to the Battle Group Commander.

All carrier Strike Operations Centers are equipped with a desk-top BASIC computer system (64K memory). Properly programmed, this computer is suitable for rapid and accurate computation and retrieval of aircraft performance and fuel usage data.

The purpose of this thesis was to investigate the feasibil- of developing a mission planning computer program for A-7E aircraft suitable for on-board carrier use by a strike planner. This program, in conjunction with similar programs for other types of strike aircraft, will allow the planner to quickly and accurately predict mission capability and fuel requirements for various types of missions for an entire strike group.

The NATOPS Flight Manuals are the only authorized standard of the U. S. Navy for "... information on all aircraft systems, performance data, and operating procedures required for safe and effective operations" [Ref. 1]. The development of a computer program to predict aircraft performance requires the use of a data reduction technique to represent the NATOPS performance graphs as numeric equations. Computational methods to reduce the graphs to equations were investigated in a previous thesis of June 1978 by then LCDR W. M. Siegel [Ref. 2]. Siegel devised a procedure to represent each curve in the A-7E takeoff performance charts by a Least Squares Fit polynomial. This technique of curve fitting is described in Appendix A. For a family of takeoff curves, he cross-plotted the coefficients of the polynomials to develop a single multi-variable equation which represented the entire family of takeoff curves. This technique of cross-plotting coefficients is illustrated with an example in Appendix B. Siegel's work was continued by Lieutenant G. L. Koger in his thesis of September 1978 [Ref. 3]. Using Siegel's method, Koger reduced nine A-7E

performance charts to computer algorithms for use on the HP9830 desk computer and the TI-59 hand calculator. Although useful in defining the problems of reducing performance data, Siegel and Koger's products were not suitable for use by a strike planner inasmuch as Siegel's thesis was limited to takeoff performance and Koger's thesis did not address the computation of drag changes with varying flight conditions. Koger also excluded from his investigation those performance charts that did not accurately reduce by Siegel's method.

B. GOALS

The desired product of this thesis was an interactive BASIC computer program which would compute performance and fuel usage data for the A-7E aircraft and would be compatible with a 64K memory desk-top calculator. The program would have the flexibility to compute data for any land and carrier-based mission and for any authorized weapons load. The desired program would simplify and improve the accuracy of mission planning, and would be used routinely by airwing and strike operations personnel.

II. PROBLEM APPROACH

A. PROGRAM DESIGN

The program was developed using the Waterloo BASIC compiler of the IBM 3033 Computer at the Naval Postgraduate School.

The following basic outline was used to design the computer program:

1. Develop an algorithm to compute drag count each time a flight condition changed.
2. Represent each performance graph in numeric form.
3. Develop an interface program to tie together user inputs, drag computations, and performance calculations, and to output performance data.
4. Tailor the program to be " user-friendly " through error retrieval and text explanations.
5. Validate the product program for accuracy and assess its operational usefulness through qualitative evaluation by fleet pilots.

Whole missions were represented by combinations of mission segments reconstructed for a specific mission in a specific order to allow for use of subprograms. The mission segments to be chosen repetitively in order of mission occurance were

1. Takeoff and Acceleration
2. Rendezvous
3. Low Altitude Cruise
4. Climb
5. Cruise
6. Descent
7. Attack
8. Tanking
9. End of Mission

This technique of representing a mission in segments gives the planner much flexibility to use the program for all

types of departures, recoveries, and complicated hi-lo profiles.

B. RESTRICTIONS

The following restrictions were placed on the program in order to reduce the memory requirement to that available on the candidate computer system:

1. The NATOPS manual would be the sole source of performance data.
2. Error retrieval would be minimized. This would make the program more difficult to use but would save computer space for computations.
3. No attempt would be included to limit the flight envelope of the airplane or to limit the combinations of stores to only those currently authorized for carriage. Such limiting would require memory-consuming conditional steps.
4. It would be assumed that the user would be familiar with A-7E flight characteristics, carriage and loading restrictions, and carrier flight procedures. This assumption would minimize the effects of restrictions 2. and 3. above.
5. A single repetitive method of curvefit would be used. Although using different curvefit techniques for different graphs would result in greater accuracy, a Least Squares Fit Polynomial Curvefit, with minor corrections as necessary, gave acceptable results, and allowed for one repetitive algorithm. This feature was paramount for containing the program to the size of available computer memory.

III. SOLUTION

A. DRAG COMPUTATIONS

All the performance graphs in the NATOPS Manual depict the performance of a clean aircraft (no external stores). The types of drag which must be calculated to access the graphs when loaded with external stores are basic store drag, interference drag, and trim drag. The data to compute each of these is located in Figure 11-18, Sheets 1-14, of the NATOPS Manual. A sample page is included as figure C1, Appendix C. Basic store drag is the parasite drag penalty imposed when carrying external stores. It increases with airspeed for any load. Interference drag is the drag resulting from pressure buildup between stores on adjacent wing stations. It varies with the distance between adjacent stores, the airspeed the stores are carried, and with configuration type (multiple or single-loaded). Trim drag is the drag due to assymetric loading and is a function of rolling moment. The manual calculation technique for each type of drag is detailed in Chapter 11, NATOPS. A computer algorithm was written to compute each drag and to sum the effects each time the aircraft configuration or flight condition changed.

1. Basic Store Drag

Inputting a matrix of every possible configuration

drag count was impractical as a result of limited program memory; therefore, the following algorithm was developed to determine basic drag count:

1. As a response to a program prompt, basic drag count values for Mach .6, .7, .8, and .9 are entered for each station. Column 3, Figure C1, Appendix C lists sample input data which is extracted from the NATOPS Manual.
2. The cumulative drag count for each respective Mach is added and the program computes a Least Squares Fit equation of cumulative basic drag count (DC) versus Mach (M) of the form

$$DC = A + BM + CM^2$$

   where A, B, and C are curvefit coefficients.
3. The user can now enter with any Mach and determine the total basic drag for that Mach.

2. Interference Drag

The following algorithm details the calculation of interference drag:

1. As a program response, the distance from the pylon centerline to the edge of the loaded store is entered for each station. This data is located in Column 4, Figure C1, Appendix C.
2. The configuration status (multiple or single) is next entered.
3. The program computes the distance between adjacent stores.
4. Depending on the configuration load and the adjacent stores involved, the interference drag is computed directly from a linear relationship between interference drag count and distance between stores. For outboard wing stations this relationship is depicted in Figure C2, Appendix C. For inboard wing stations, this relationship is depicted in Figure C3, Appendix C.

3. Trim Drag

The following algorithm details computation of trim drag:

1. The asymmetric rolling moment of the desired load is

entered. This data is listed in Column 6, Figure 11-18, NATOPS, and sample data is shown in Column 6, Figure C1, Appendix C.

2. A family of curves representing the relationship between rolling moments and trim drag (Figure C4, Appendix C) is reduced to a single multi-variable equation by the method of cross coefficients described in Appendix B.
3. For an input of rolling moment, Mach, and altitude, the trim drag is calculated.

B. NUMERIC REDUCTION OF GRAPHS

The NATOPS Manual performance curves were constructed from experimental data. In most cases the curves of a specific graph can be accurately approximated by a curve family of a single order (all the curves on a specific chart are of the same order). Figure 1, Service Ceiling and Optimum Endurance Altitude, illustrates this feature. Every curve in this chart can be represented by a second order polynomial. The method of cross-coefficients described in Appendix B reduces this type of chart to numeric form very accurately with no additional steps. Some families of curves have unusual or uneven spacing and the curves cannot be accurately represented by a single polynomial type. An example of this is illustrated in Figure 2, Military Power Climb. This type of chart can be segmented into two or three segments by inspection, and the method of cross-coefficients is applied to each segment individually. Conditional statements in the program select the desired segment of data. This technique gives results comparable to manual graphical extraction of data. Some charts, such as the Military Power Climb Speed Schedule, Figure 3, are composed of a single curve which can be

CRUISE CEILING AND OPTIMUM ENDURANCE ALTITUDE

MODEL: A-7E
DATA BASIS. FLIGHT TEST
DATE: NOVEMBER 1971

ENGINE: TF41-A-2
FUEL GRADE: JP-5
FUEL DENSITY: 6.8 LB/GAL

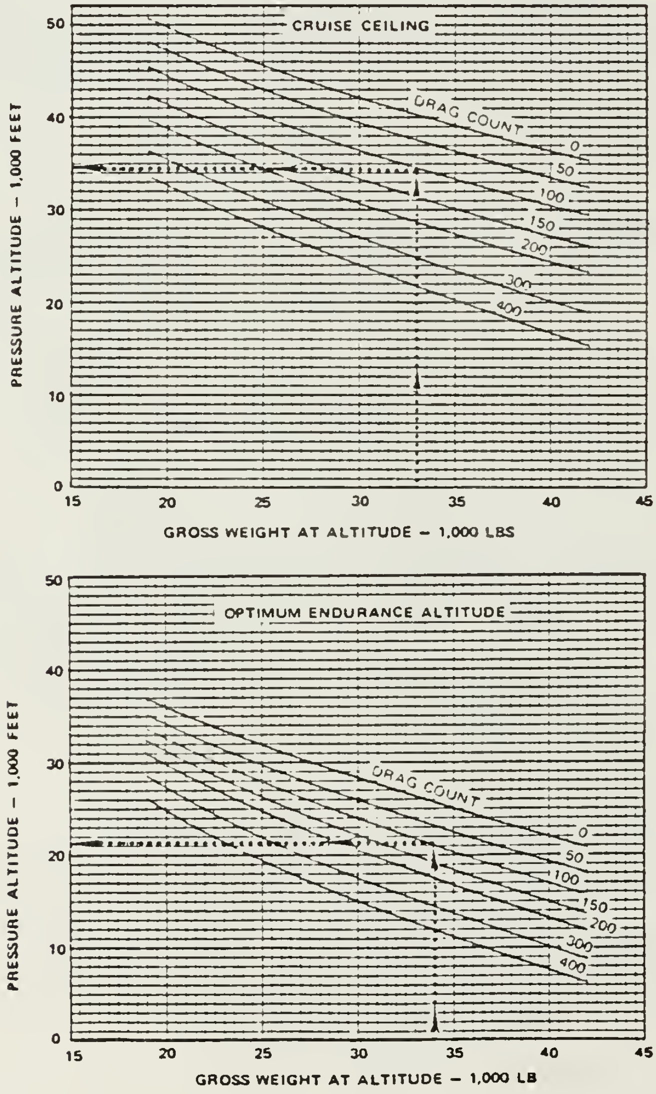

Figure 1.

MILITARY POWER CLIMB

FUEL REQUIRED TO CLIMB FROM SEA LEVEL TO SELECTED ALTITUDE

MODEL: A-7E
DATA BASIS: FLIGHT TEST
DATE: NOVEMBER 1971

ENGINE: TF41-A-2
FUEL GRADE: JP-5
FUEL DENSITY: 6.8 LB/GAL

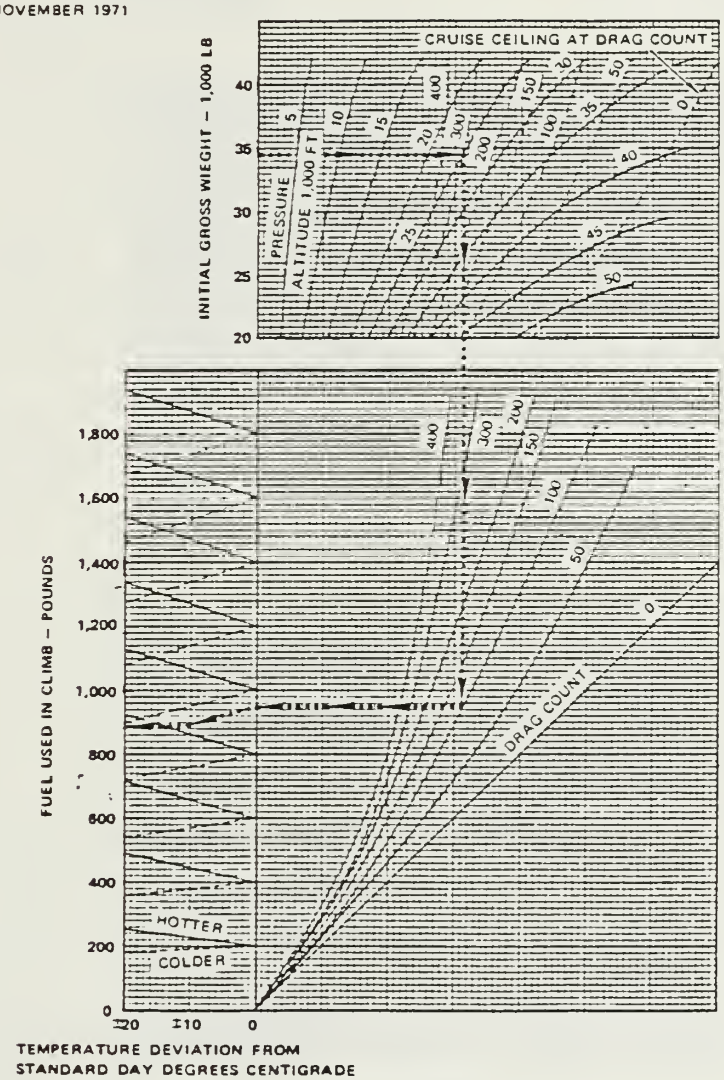

Figure 2.

MILITARY POWER CLIMB

CLIMB SPEED SCHEDULE

MODEL: A-7E
DATA BASIS: FLIGHT TEST
DATE: NOVEMBER 1971

ENGINE: TF41-A-2
FUEL GRADE: JP-5
FUEL DENSITY: 6.8 LB/GAL

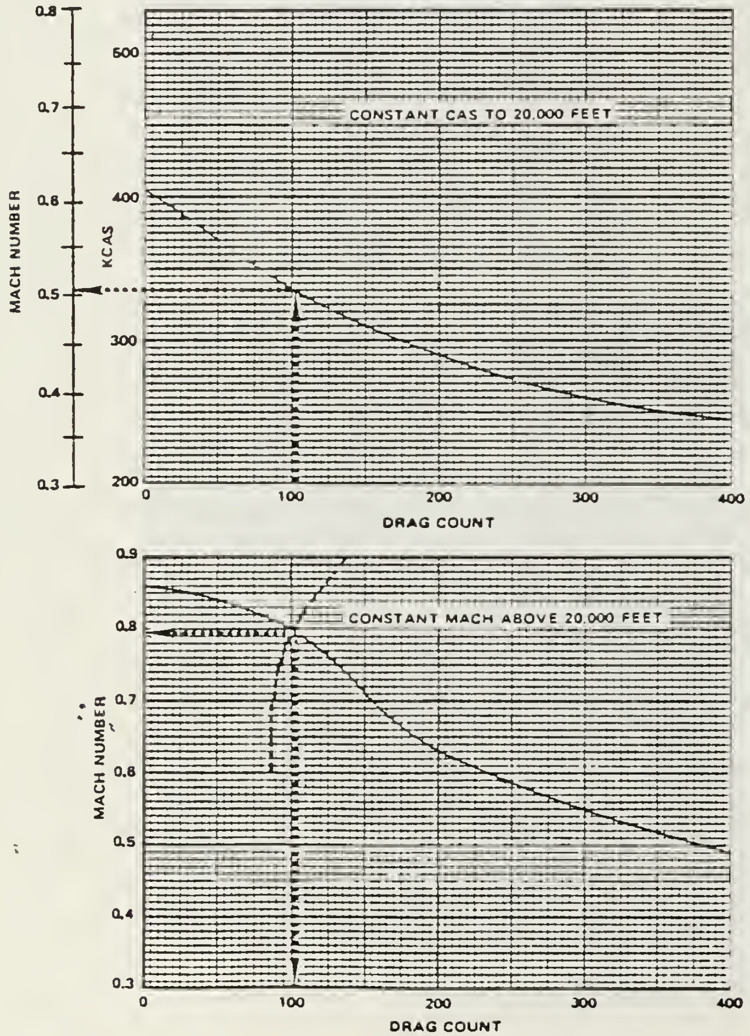

Figure 3.

represented by a simple equation. For the top curve of Figure 3, the resultant equation form is

$$KCAS = 404.5 - .75\ (DRAG) + .001\ (DRAG)^2$$

C. PROGRAM DESCRIPTION

The program was organized into four major sections as follows:

1. Data Input

    a. Basic Configuration Segment

    User inputs are numbers of pylons, ejector racks, missile racks, drop tanks, and air refueling stores.

    b. Basic Store Drag Segment

    User inputs are basic store drag count values for each station by Mach number.

    c. Interference Drag Segment

    User inputs are type of store and distance from pylon centerline to the edge of the store for each station.

    d. Trim Drag Segment

    The user input is total asymmetric rolling moment of the configuration.

2. Total Drag Subroutine

    User inputs are Mach, gross weight, and altitude. Computer generated inputs are 1. a., b., c., and d. above. Program output is total drag count.

3. Takeoff and Acceleration Segment

    User inputs are takeoff gross weight, takeoff fuel state, acceleration speed after takeoff, and takeoff

elevation. Computer outputs are distance and fuel required, new fuel state, and new gross weight.

4. Mission Menu

The mission was divided into the following profile segments which the user selected in the order of specific mission occurance:

a. Low Altitude Cruise

Used for emission control departures, other carrier departures and recoveries, low level ingress/ egress, and radar masking profiles. User inputs are Mach, route distance, and flight level temperature. Computer generated inputs are current gross weight, fuel at the beginning of the segment, and drag count. Outputs are fuel flow, fuel used this segment, and new gross weight and fuel state.

b. Climb

User inputs are starting and level-off altitudes. Computer generated inputs are current gross weight, fuel state, and drag count. Outputs are recommended climb speed, maximum range and maximum endurance altitudes for the configuration, fuel and distance required to climb, and new gross weight and fuel state.

c. Rendezvous

User inputs are rendezvous altitude, airspeed, refueling onload/ offload, and time in rendezvous. Computer generated inputs are current fuel state, gross weight, and drag count. Outputs are fuel used in rendezvous, new gross weight, and new fuel state.

d. High Altitude Cruise

User inputs are cruising altitude, Mach, temperature at altitude, and segment distance. Computer generated inputs are true airspeed, calibrated airspeed, drag count, current gross weight, and fuel state. Outputs are fuel flow, fuel used, new gross weight, and updated fuel state.

e. Maximum Range Descent

User inputs are starting and level-off altitudes. Computer generated inputs are drag count, current fuel state, and gross weight. Outputs are maximum range descent speed, distance and fuel used in the descent, new gross weight, and fuel state.

f. Attack

User inputs are estimated fuel used for the attack and ordnance weight expended at the target. Computer generated inputs are current gross weight and fuel state. Outputs are new configuration status for drag determination, new gross weight, and updated fuel state.

g. Tanking

This segment pertains to enroute tanking by the strike aircraft going to or from the target. It also is used for mission planning for the tanker aircraft. User inputs are onload or offload fuel quantity, tanking speed, tanking altitude, time required to tank, and temperature at altitude. Computer generated inputs are current fuel state, weight, and

drag count. Outputs are new fuel state, gross weight, and net fuel gained or lost.

h. End of Mission

This segment administratively ends the profile and allows for restart or termination of the program. It also summarizes the end-of-mission fuel state and gross weight.

D. PROGRAM ANOMALIES

The NATOPS charts are so constructed that the data are accurate for only those regions on the charts where data are displayed. As an example, cruise information for the flight regime at the backside of the power curve is not displayed on any chart even though the aircraft can be flown in stabilized flight in that region. It is improper to extrapolate data for cruise conditions at airspeeds below maximum endurance from the NATOPS charts. The computer program will give you data for this region, but this data will be in error. Similarly, data can be obtained for airspeeds which exceed aircraft capabilities, but this data are inaccurate also. Other flight regimes that are not accurately represented in the performance charts or in the program are landing configuration performance data (gear and/or flaps down), penetration descent data (speedbrake out), partial power climb data, and level acceleration/deceleration data. Manuevering performance data was beyond the scope of this investigation.

IV. RESULTS

The program which resulted from this investigation is located in Appendix D. The program reduces all or part of the following graphs to numerical form (the graphs are listed by name and page number as they appear in NATOPS):

1. Military Power Climb Speed Schedule (p. 11-54)
2. Fuel Required To Climb From Sea Level (p. 11-57)
3. Distance Required To Climb From Sea Level (p. 11-57)
4. Cruise Ceiling And Optimum Endurance Altitude (p. 11-59)
5. Maximum Range Cruise At Constant Altitude (p. 11-68)
6. Cruise Performance, Aircraft Reference Number (p. 11-64)
7. Cruise Performance, Lbs Per Nautical Mile (p. 11-65)
8. Cruise Performance, Fuel Flow (p. 11-66)
9. Cruise Performance, Clean Aircraft Transfer Scale (p. 11-63)
10. Maximum Endurance Speed (p. 11-71)
11. Maximum Range Descent Fuel Required (p. 11-77)
12. Maximum Range Descent Distance To Descend (p. 11-78)
13. Maximum Range Descent Speed (p. 11-75)
14. Interference Drag (p. 11-36, 37)
15. Trim Drag Due To Asymmetric Store Loading (p. 11-38)

The program, which accurately computes the total drag count for any configuration or flight condition, is interactive for a knowledgeable user and conforms to the memory size of candidate computers. The product of the program is mission performance data for a variety of missions, and the initial statement of purpose that the product be at least as accurate as the performance predictions derived from manual extraction of data from the NATOPS graphs is satisfied.

The program was tested for operational suitability by a sample group of Navy A-7E pilots at the Naval Postgraduate

School. Several representative missions were simulated. All agreed the program gave results consistent with their experience and that the program has excellent operational utility. Most of the pilots agreed that a user manual to accompany the program would reduce input errors and make the program easier to use.

V. CONCLUSIONS AND RECOMMENDATIONS

This investigation resulted in the development of an interactive computer program for the A-7E aircraft which can be used by mission planners to predict performance and fuel usage data. As a result of this investigation the following is concluded:

1. The NATOPS performance charts can be reduced to numeric form suitable for computer manipulation through math modeling techniques such as curve-fitting and cross-plotting coefficients.
2. The presentation of NATOPS performance data by computer methods can provide a quick and accurate planning tool with which planners can predict performance and fuel usage data.
3. Mission Planning computer programs that are derived from the NATOPS performance charts, and which can be implemented on desk-top calculators, can be developed for other aircraft types.
4. The memory available in most current 64K desk-top computers is satisfactory for program implementation. Increased memory size would allow for more explanatory text and error retrieval and would make the programs easier to use.

In view of the results of this investigation, recommendations involving future testing and implementation of mission planning programs are listed.

1. The accuracy of the A-7E Mission Planning Program should be verified through flight test.
2. Similar programs should be developed for other strike aircraft.
3. A NAVAIR sponsored activity should be assigned the task of managing the development, standardization, updating, and distribution of mission planning programs.
4. Planning programs for all strike aircraft should be standardized in format and combined into a Mission Planning Package for air wing and strike operations use.

APPENDIX A

LEAST SQUARES FIT APPROXIMATION

Reference 4 describes in detail the Least Squares Fit approximation. The problem in general is to describe a set of "N" data points (X,Y) by a polynomial expression of a curve whose degree is less than "N" and of the form

$$Y = A + BX + CX^2.$$

An example of the numeric procedure is as follows:

1. Given the following data points,

X	0	1	2	4	5
Y	0	1	4	11	13

with the desired equation form being

$$Y = A + BX + CX^2$$

substitute each pair of data into the desired equation form to develop the base equations:

$$\begin{aligned} 0 &= A + 0B + 0C \\ 1 &= A + 1B + 1C \\ 4 &= A + 2B + 4C \\ 11 &= A + 4B + 16C \\ 13 &= A + 5B + 25C \end{aligned}$$

2. Multiply each base equation by its coefficient of "A" and add the equations:

$$\begin{array}{r} 0(0 = A + 0B + 0C) \\ 1(1 = A + 1B + 1C) \\ 1(4 = A + 2B + 4C) \\ 1(11 = A + 4B + 16C) \\ 1(13 = A + 5B + 25C) \\ \hline 29 = 5A + 12B + 46C \end{array}$$

3. Multiply each base equation by its coefficient of "B" and add the equations:

$$
\begin{array}{r}
0(0 = A + 0B + 0C) \\
1(1 = A + 1B + 1C) \\
2(4 = A + 2B + 4C) \\
4(11 = A + 4B + 16C) \\
5(13 = A + 5B + 25C) \\
\hline
118 = 12A + 46B + 198C
\end{array}
$$

4. Multiply each base equation by its coefficient of "C" and add the equations:

$$
\begin{array}{r}
0(0 = A + 0B + 0C) \\
1(1 = A + 1B + 1C) \\
4(4 = A + 2B + 4C) \\
16(11 = A + 4B + 16C) \\
25(13 = A + 5B + 25C) \\
\hline
518 = 46A + 198B + 898C
\end{array}
$$

5. Solve the three equations for the three unknowns:

$$
\begin{aligned}
29 &= 5A + 12B + 46C \\
118 &= 12A + 46B + 198C \\
518 &= 46A + 198B + 898C
\end{aligned}
$$

$A = -.458 \quad B = 1.979 \quad C = .164$

6. The desired equation is

$$Y = -.458 + 1.979X + .164X^2$$

7. The following chart depicts the original data and the curve fit data:

X	0	1	2	4	5
Y	0	1	4	11	13
Y Fitted	-.458	1.68	4.16	10.08	13.53

8. The original and curve-fitted data are displayed graphically in Figure A1.

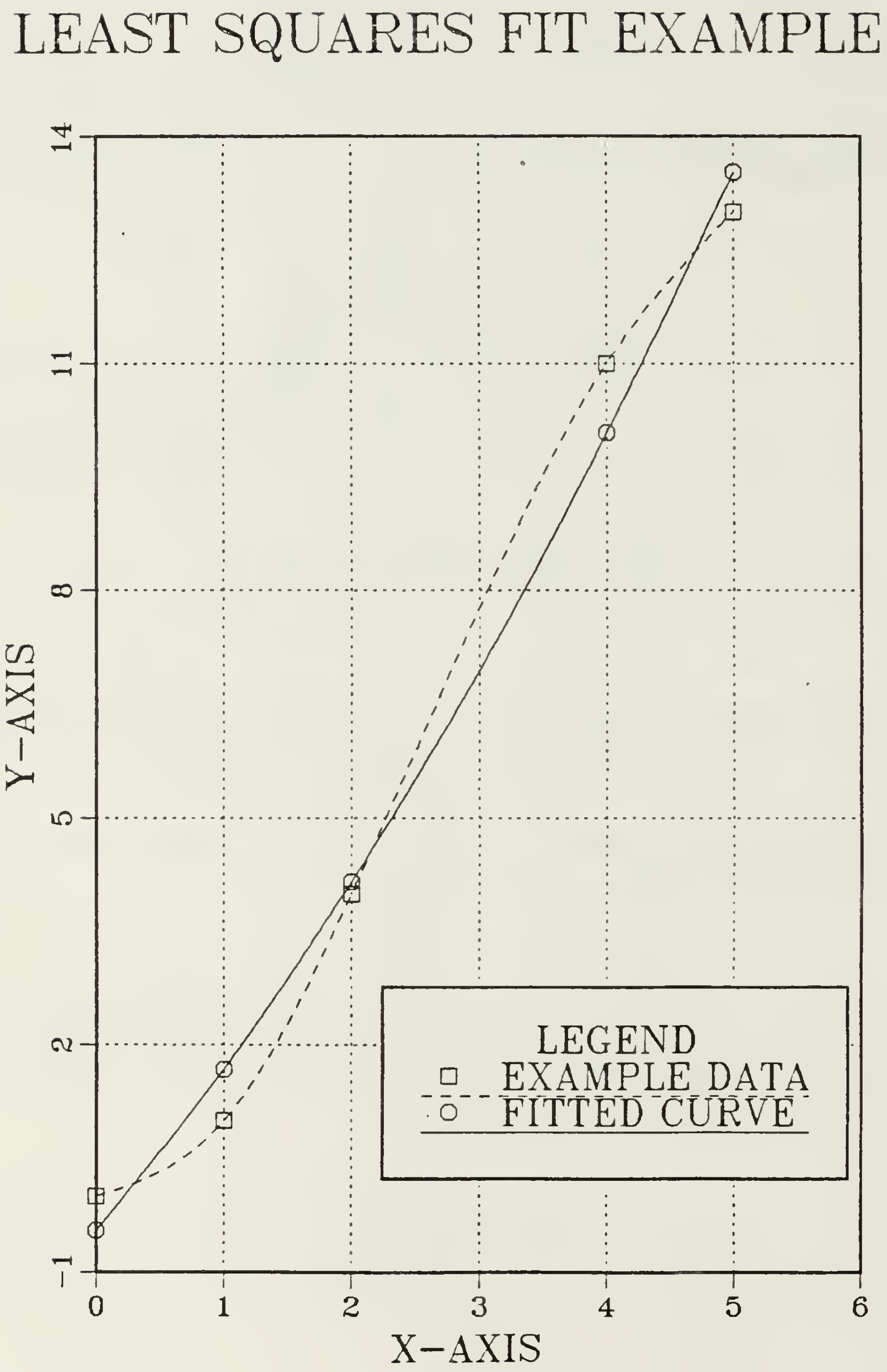
LEAST SQUARES FIT EXAMPLE
14
11
8
5
2
-1
Y-AXIS
0
1
2
3
4
5
6
X-AXIS
LEGEND
EXAMPLE DATA
FITTED CURVE

Figure A1.

APPENDIX B

PERFORMANCE CHART REDUCTION

Most of the NATOPS performance charts contain three variables (two independent and one dependent) and are depicted on a two-dimensional graph with the dependent variable illustrated as a family of curves. Figure B1, taken from the NATOPS, shows an example of this feature. The reduction of such charts is accomplished as follows:

1. Determine the order of the family of curves. For this example the curves are all nearly straight lines and are assumed to be first order represented by the equation form

   $$CAS = A + (B \times GW)$$

   where "A" and "B" are coefficients to be determined.
2. Apply a Least Squares Fit approximation to each curve. The results are

Drag (DR)	Equation:	CAS = A + (B X GW)
0	CAS =	110.9 + (4.6 X GW)
50	CAS =	108.4 + (4.3 X GW)
100	CAS =	108.0 + (4.0 X GW)
200	CAS =	107.4 + (3.6 X GW)
300	CAS =	104.6 + (3.4 X GW)

3. Graph the "A" coefficients versus the dependent variable Drag. The "A" coefficients for this example are graphed in Figure B2. Determine a Least Squares Fit approximation for the resulting curve. The result for this example is

   $$A = 110.84 - .0618\,(DR) + .0004\,(DR)^2$$

4. Graph the "B" coefficients versus the dependent variable Drag. See Figure B3 for a graph of "B" coefficients for this example. Determine a Least Squares Fit approximation for the resulting curve. The result for this example is

   $$B = 4.5471 - .0059\,(DR)$$

5. Apply the coefficients to the original equation form of

$$CAS = A + (B \times GW)$$

For our example the final equation becomes

$$CAS = [\ 110{,}84 - .0618\ (DR) + .0004\ (DR)^2\ ] + [\ 4.5471 - .0059\ (DR)\ ] \times GW$$

6. For any entry of drag and gross weight, the descent airspeed results. Sample comparisons are listed:

Gross Weight (1000 lbs)	Total Drag Count	Graphical Solution (CAS)	Numerical Solution(CAS)
24	50	211	211
30	100	228	227
32	175	226	225
36	200	237	236

MAXIMUM RANGE DESCENT

DESCENT SPEEDS

MODEL: A-7E
DATA BASIS FLIGHT TEST
DATE: NOVEMBER 1971

ENGINE: TF41-A-2
FUEL GRADE: JP-5
FUEL DENSITY: 6.8 LB/GAL

CONDITIONS:
IDLE THRUST
STANDARD DAY

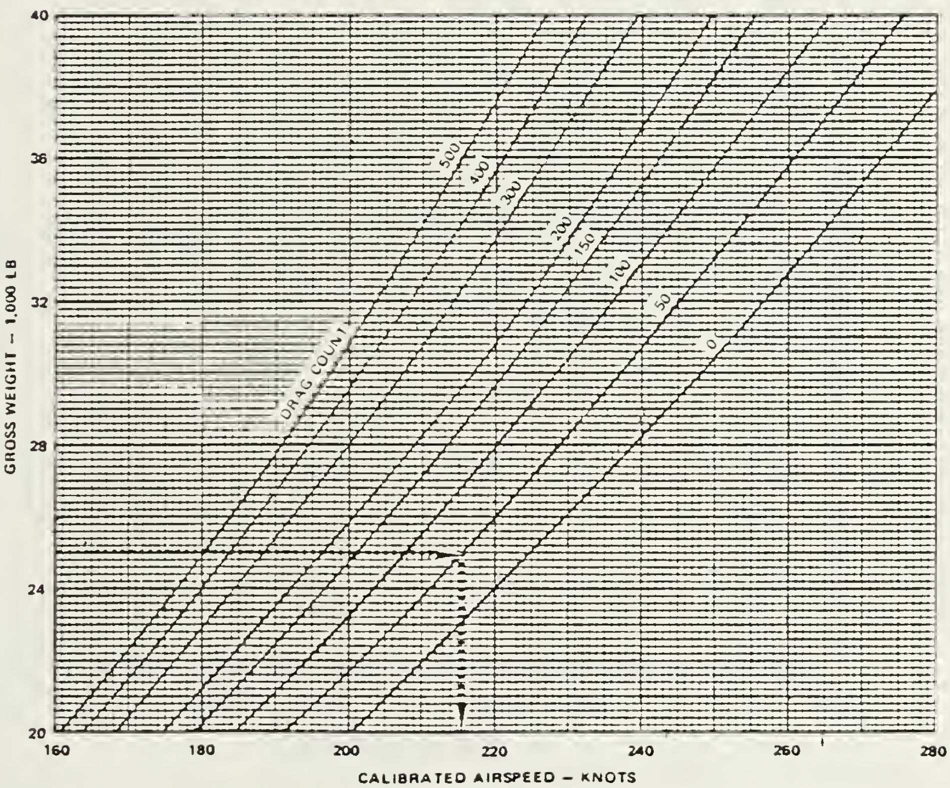

Figure B1.

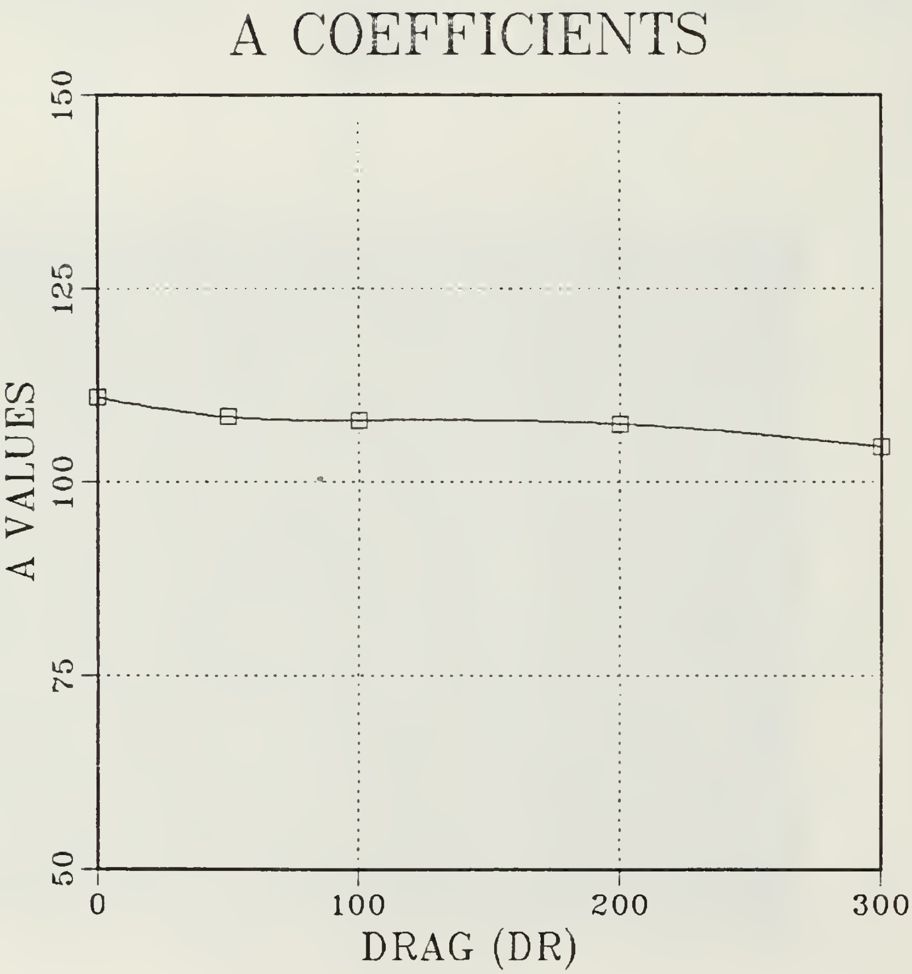

Figure B2.

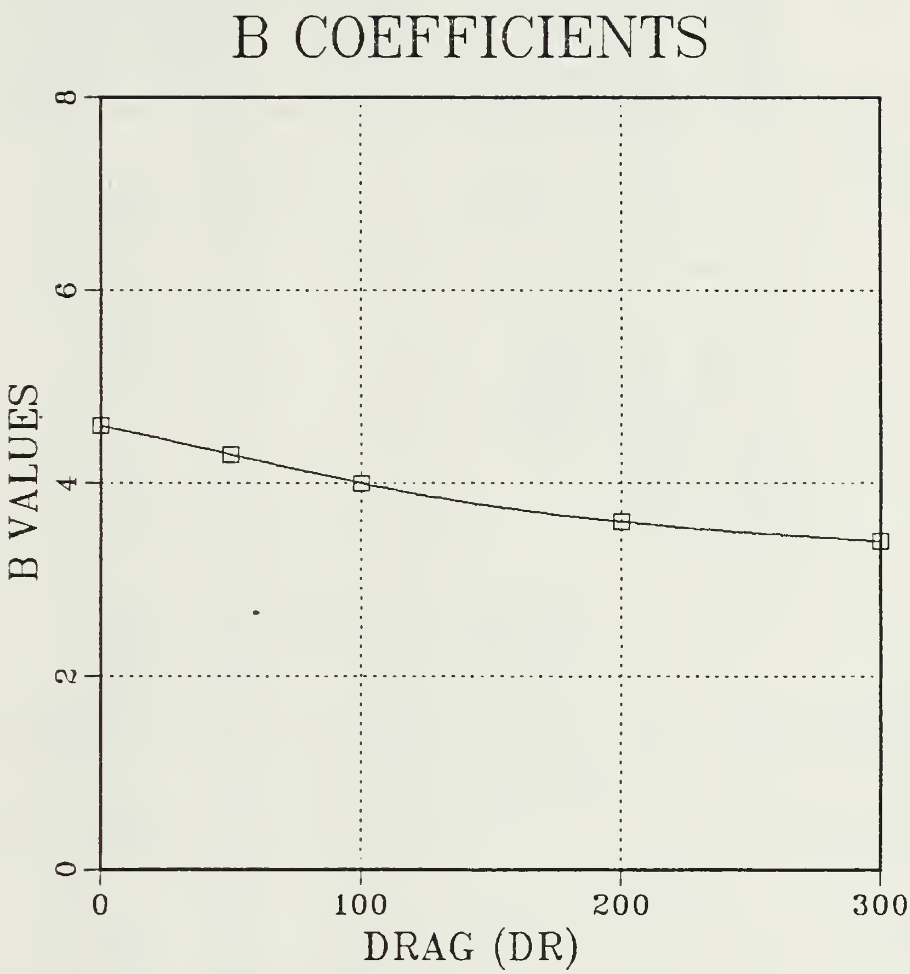

Figure B3.

APPENDIX C

A-7E NATOPS DRAG DATA CHARTS

STORES COMPUTATIONS

(1) STORE	(2) MOUNT/NO. OF STORES	(3) BASIC DRAG COUNT (Note 1) MN =0.6	MN =0.7	MN =0.8	MN =0.9	(4) DISTANCE FROM PYLON CENTER TO EDGE OF STORE IN INCHES (Note 2)	(5) WEIGHT IN LBS (Note 3)	(6) ROLLING MOMENT FT LBS (Note 4) Sta 1 or 8 / Sta 2 or 7 / Sta 3 or 6	REMARKS
BOMBS (Continued)									
Mk 36 Destructor	MER/6	58.5	60.5	68.5	90.5	14.5	3,636	41,562 29,557 18,610	
	MER/4	46.5	48.5	55.6	73.5	14.5	2,494	28,555 20,307 12,786	
	MER/2	36.0	36.0	42.0	57.0	5.5	1,354	15,547 11,057 6,962	
	TER/3	37.5	39.0	51.0	76.5	14.5	1,806	20,707 14,726 9,272	
	TER/2	29.0	30.5	41.5	64.5	14.5 5.5	1,236	14,203 10,101 6,360	
	PR/1	9.5	10.5	14.0	23.0	5.5	570	6,504 4,625 2,912	
Mk 40 Destructor	PR/1	8.0	9.0	12.5	20.5	7.25	1,057	11,891 8,456 5,324	
FIRE BOMBS									
Mk 77 Fire Bomb	PR/1	16.0	16.5	17.0	26.0	9.37	520	5,923 4,212 2,652	
PRACTICE BOMBS									
Mk 76 Practice Bomb	MER/6	28.0	30.0	33.5	48.5	9.18	361	4,180 2,973 1,872	

76E263(5)-01-80

Figure C1.

INTERFERENCE DRAG

(For Determining Interference Drag Between Stations 1 and 2 or 7 and 8)

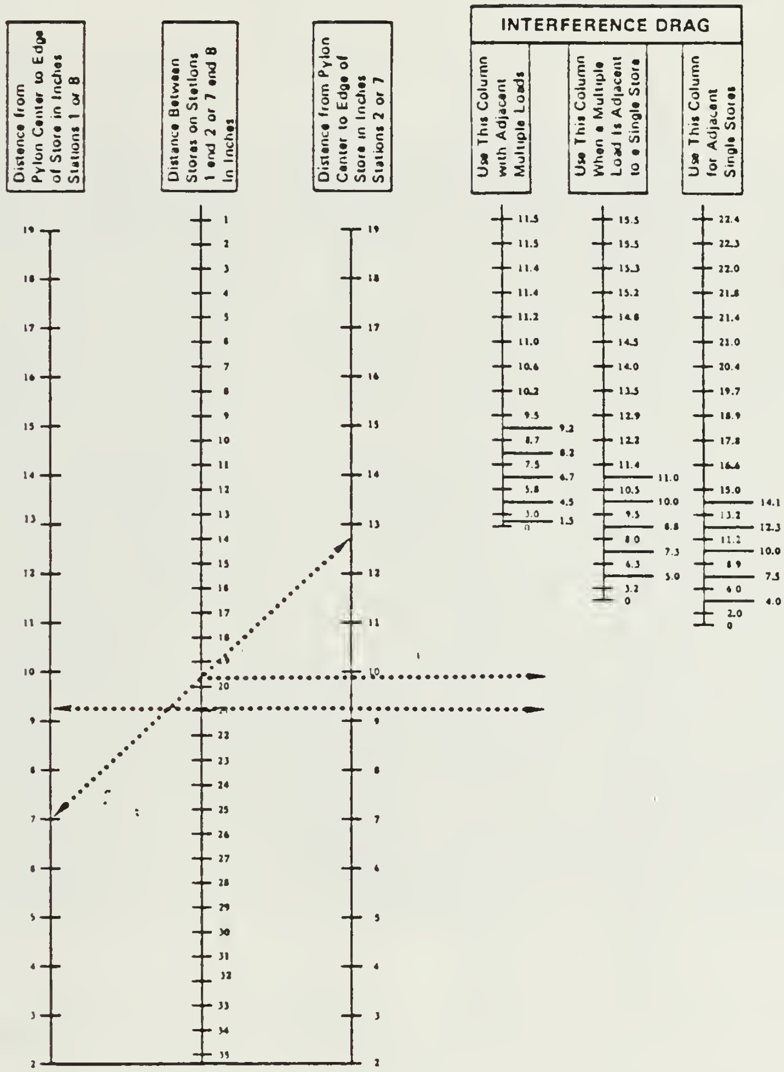

Figure C2.

INTERFERENCE DRAG

(For Determining Interference Drag Between Stations 2 and 3 or 6 and 7)

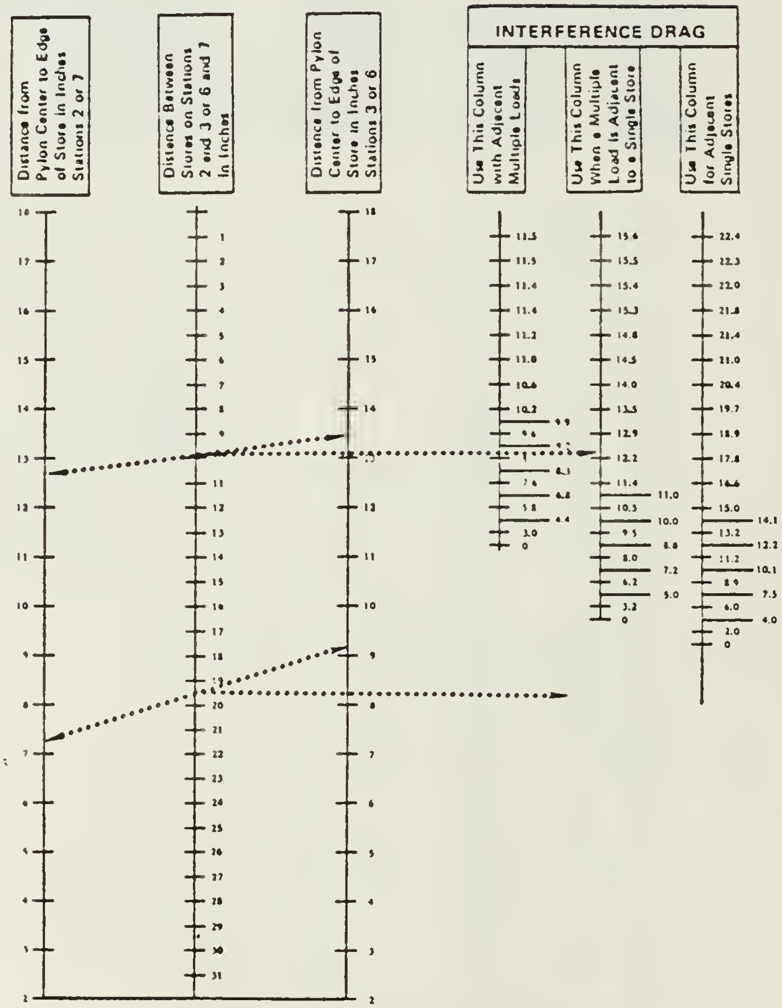

Figure C3.

TRIM DRAG DUE TO ASYMMETRICAL STORE LOAD

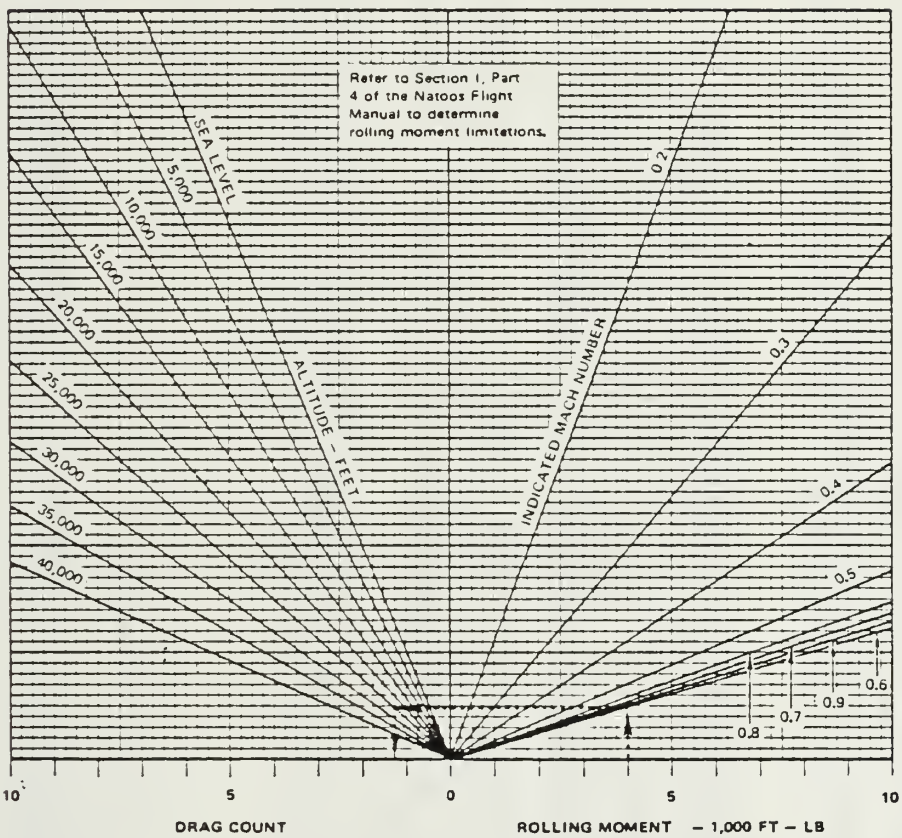

Figure C4.

APPENDIX D

A-7E MISSION PLANNING PROGRAM

```
00001 PRINT 'THIS PART OF THE PROGRAM ASKS YOU QUESTIONS ABOUT YOUR MISSION'
00002 PRINT 'LOAD. LOAD AND DRAG DATA ARE FOUND IN NATOPS, CHA 11, FIG 11-18.'
00003 PRINT 'IF YOUR EXACT LOAD IS NOT LISTED, INTERPOLATE TO GET REPRE-'
00004 PRINT 'SENTATIVE FIGURES FOR YOUR LOAD VS MACH.'
00005 PRINT 'WHEN READY WITH YOUR LOAD AND PROFILE, ANSWER THE QUESTIONS AS'
00006 PRINT 'THEY APPEAR. TORA  TORA  TORA '
00007 PRINT
00008 DIM BDC(8),SM(8,4),T(8),CD(8),DIS(16),BA(4),TA(4),B(11),C(66),PP(4)
00009 F1=0
00010 F2=0
00011 OPTION PRTZC 14
00012 PRINT
00013 PRINT 'HOW MANY MERS ARE LOADED (ENTER A NUMBER) ?'
00014 ON CONV GOTO 29
00015 INPUT MER
00016 PRINT 'HOW MANY TERS ARE LOADED (ENTER A NUMBER) ?'
00017 ON CONV GOTO 29
00018 INPUT TER
00019 PRINT 'HOW MANY DROPS/BUDDY STORES ARE LOADED ?'
00020 ON CONV GOTO 29
00021 INPUT DP
00022 PRINT 'HOW MANY ARM MISSLE RACKS ( AERO 5 ) ARE LOADED ?'
00023 ON CONV GOTO 29
00024 INPUT AM
00025 PRINT 'HOW MANY PYLONS ARE PHYSICALLY ABOARD (ENTER A NUMBER) ?'
00026 ON CONV GOTO 29
00027 INPUT PY
00028 GO TO 31
00029 PRINT 'YOUR LAST ENTRY WAS IN ERROR . TRY AGAIN :'
00030 GO TO 12
00031 FOR I= 1 TO 8
00032 BDC(I)=0
00033 T(I)=0
00034 CD(I)=0
00035 NEXT I
00036 FOR I= 1 TO 8
00037 M = .6
00038 FOR J= 1 TO 4
00039 PRINT
00040 PRINT 'FOR THE LOAD ON STATION',I,'ENTER THE BASIC DRAG COUNT FOR'
00041 PRINT ' MACH =',M
00042 ON CONV GOTO 45
00043 INPUT SM(I,J)
00044 GO TO 47
00045 PRINT 'YOUR DRAG COUNT ENTRY IS IMPROPER. CHECK YOUR VALUE'
00046 GO TO 40
00047 M=M+.1
00048 NEXT J
```

```
00049 TI=0
00050 IF ((I=4) OR (I=5)) THEN 85
00051 IF ((I=3) OR (I=6)) THEN 63
00052 PRINT
00053 PRINT 'FOR STATION',I,'ENTER THE DISTANCE IN INCHES FROM THE PYLON'
00054 PRINT 'CENTER TO THE INBOARD STORE EDGE (NATOPS,FIG 11-18,COL4).'
00055 PRINT 'IF NO STORE IS LOADED OR THE VALUE IS NOT GIVEN ENTER A ZERO (0).'
00056 ON CONV GOTO 59
00057 INPUT DIS(I)
00058 IF (DIS(I)<0 OR DIS(I)>18) THEN 59 ELSE 62
00059 PRINT
00060 PRINT 'YOUR ENTRY WAS OUT-OF-RANGE OR IMPROPER, CHECK YOUR VALUE'
00061 GO TO 52
00062 GO TO 74
00063 PRINT
00064 PRINT
00065 PRINT 'FOR STATION',I,'ENTER THE DISTANCE IN INCHES FROM THE PYLON'
00066 PRINT 'CENTER TO THE OUTBOARD STORE EDGE (NATOPS, FIG 11-18,COL4).'
00067 PRINT 'IF NO STORE IS LOADED OR THE VALUE IS NOT GIVEN ENTER A ZERO (0).'
00068 ON CONV GOTO 71
00069 INPUT DIS(I)
00070 IF (DIS(I)<0 OR DIS(I)>18) THEN 71 ELSE 74
00071 PRINT
00072 PRINT 'YOUR ENTRY WAS IMPROPER. CHECK YOUR VALUE AND TRY AGAIN.'
00073 GO TO 63
00074 IF ((I=2) OR (I=7)) THEN 75 ELSE 81
00075 PRINT
00076 PRINT 'FOR STATION',I,'ENTER THE DISTANCE IN INCHES FROM THE PYLON'
00077 PRINT 'CENTER TO THE OUTBOARD STORE EDGE (NATOPS, FIG 11-18, COL4).'
00078 PRINT 'IF NO STORE IS LOADED OR THE VALUE IS NOT GIVEN, ENTER A ZERO (0).
00079 INPUT DIS(2*I)
00080 PRINT
00081 PRINT 'FOR STATION',I,'IF THE STORE IS A SINGLE TYPE OR EMPTY'
00082 PRINT 'TYPE IN A ONE (1).OTHERWISE TYPE IN A ZERO (0) FOR A MULTIPLE'
00083 PRINT 'TYPE STORE.'
00084 INPUT T(I)
00085 NEXT I
00086 PRINT
00087 PRINT ' FOR YOUR LOAD ENTER THE ASSYMMETRIC ROLLING MOMENT IN '
00088 PRINT 'FT-LBS ( IE., ENTER 5000 FT-LBS AS 5000 ):'
00089 INPUT RM
00090 RM=RM/1000
00091 FOR J = 1 TO 4
00092 FOR I = 1 TO 8
00093 BDC(J) = SM(I,J)+ BDC(J)
00094 NEXT I
00095 NEXT J
00096 CD(1)= (39.4) - DIS(1) - DIS(4)
```

```
00097 CD(2)= 36-DIS(2)-DIS(3)
00098 CD(6)= 36-DIS(6)-DIS(7)
00099 CD(7) = (39.4) - DIS(14) - DIS(8)
00100 FOR I = 1 TO 7
00101 IF ( (I=3 OR I=4) OR (I=5) ) THEN 114
00102 IF ( T(I)+T(I+1)) = 2 THEN 111
00103 IF (T(I)+T(I+1))=0 THEN 105
00104 IF (T(I)+T(I+1))=1 THEN 108
00105 ID=17.1611-3.12*CD(I)+.5004*CD(I)**2-.0268*CD(I)**3
00106 IF CD(I) >13.5 THEN ID=0
00107 GO TO 113
00108 ID= 19.9979-2.1487*CD(I)+.2710*CD(I)**2-.0129*CD(I)**3
00109 IF CD(I) > 16.5 THEN ID = 0
00110 GO TO 113
00111 ID=23.6656-.7328*CD(I)+.0859*CD(I)**2-.0069*CD(I)**3
00112 IF CD(I) > 17.5 THEN ID = 0
00113 TI = TI +ID
00114 NEXT I
00115 GOSUB 192
00116 FOR I= 1 TO 4
00117 DIS(I)=E(I)
00118 NEXT I
00119 PRINT 'ENTER YOUR TAKE-OFF GROSS WEIGHT (ENTER 42,000 LBS AS 42000):'
00120 INPUT GW
00121 PRINT
00122 PRINT 'ENTER YOUR TAKE-OFF FUEL (10,200 LBS AS 10200):'
00123 INPUT GAS
00124 PRINT
00125 PRINT 'ENTER THE TAKE-OFF ELEVATION ( 2732 FT AS 2732 , S.L. AS 0 ):'
00126 INPUT EL
00127 PRINT
00128 PRINT 'ENTER THE SPEED TO WHICH YOU WILL ACCEL AFTER TAKE-OFF '
00129 PRINT 'IN CAS (ENTER 250 KTS AS 250):'
00130 INPUT V
00131 M=.15259*V
00132 M=INT(M)*.01
00133 PRINT
00134 GU=2*(658*M)-150
00135 D=.01*(658*M)-.5
00136 PRINT 'IT TAKES',INT(GU),'LBS AND',INT(D),'MILES TO TAKE-OFF AND ACCEL TO'
00137 PRINT V,'KTS CAS AND',M,'MACH'
00138 GAS=GAS-GU
00139 GW=GW-GU
00140 PRINT 'FUEL LEFT=',INT(GAS),'.UPDATED GROSS WT=',INT(GW)
00141 PRINT
00142 PRINT 'THE NEXT PART OF THE PROGRAM IS A MENU OF FLIGHT PROFILE'
00143 PRINT 'SEGMENTS. GO THROUGH YOUR PLANNED MISSION FROM ACCEL AFTER'
00144 PRINT 'TAKE-OFF TO END OF MISSION AS A SERIES OF PROFILE SEGMENTS.'
```

```
00145 PRINT 'PICK THE VERY NEXT PROFILE SEGMENT YOU WILL FLY BY ENTERING'
00146 PRINT 'THE APPROPRIATE NUMBER THEN ANSWER THE QUESTIONS AS THEY APPEAR.'
00147 PRINT
00148 PRINT '    1. LOW ALTITUDE CRUISE (EMCON DEPT, CASE 1 DEPT, LOW LEVEL)'
00149 PRINT '    2. CLIMB (TO RENDZ, TO ENROUTE ALT, ETC)'
00150 PRINT '    3. RENDEZVOUS WITH OR WITHOUT TANKING
00151 PRINT '    4. HI ALTITUDE CRUISE ( ABOVE 1000 FT MSL ).'
00152 PRINT '    5. DESCENT (TO START RUN-IN, TO RETURN TO BASE, ETC)'
00153 PRINT '    6. TARGET ATTACK '
00154 PRINT '    7. ENROUTE TANKING'
00155 PRINT '    8. END OF MISSION'
00156 ON CONV GOTO 171
00157 ON ERR GOTO 171
00158 PRINT
00159 PRINT 'ENTER THE NEXT PROFILE SEGMENT NUMBER:'
00160 ON CONV GOTO 171
00161 INPUT PS
00162 OX=0
00163 IF PS=1 THEN 279
00164 IF PS=2 THEN 389
00165 IF PS=3 THEN 532
00166 IF PS=4 THEN 491
00167 IF PS=5 THEN 561
00168 IF PS=6 THEN 601
00169 IF PS=7 THEN 616
00170 IF PS=8 THEN 643
00171 PRINT 'YOUR ENTRY WAS IN ERROR. TRY AGAIN :'
00172 GO TO 145
00173 FOR I= 1 TO 4
00174 TA(I)=CIS(I)
00175 NEXT I
00176 W=M
00177 IF W<.6 THEN M=.6
00178 IF F2=99 THEN 179 ELSE 181
00179 GOSUB 269
00180 RETURN
00181 TB=TA(1)+TA(2)*M+TA(3)*M**2+TA(4)*M**3
00182 A=-98.94+517.7*M-838.*M**2+430.*M**3
00183 B=58.6823-284.8642*M+446.054*M**2-223.9858*M**3
00184 C=-3.9662+21.1894*M-33.8090*M**2+17.0192*M**3
00185 D=.1037-.5588*M+.842*M**2-.3950*M**3
00186 RN=A+B*RM+C*RM**2+D*RM**3
00187 TR=(.1+.005*ALT+.00008*ALT**2)*RN
00188 DR=TI+TR+TB-6
00189 IF W<.6 THEN DR=DR-((.6-W)*DR)
00190 PRINT 'DR=',DR,'AT M=',W
00191 RETURN
00192 FOR I= 1 TO 11
```

```
00193 B(I)=0
00194 NEXT I
00195 FOR I = 1 TO 66
00196 C(I) = C
00197 NEXT I
00198 B(1)=1
00199 N=0
00200 M=.6
00201 Q=1
00202 D2=3
00203 B(2) = M
00204 Y = BDC(Q)
00205 Z=1
00206 FOR I=2 TO D2
00207 B(I+1)=B(I)*B(2)
00208 NEXT I
00209 B(D2+2)=Y
00210 R=0
00211 FOR I=1 TO D2+2
00212 FOR O=I TO D2+2
00213 R=R+1
00214 C(R)=C(R)+B(I)*B(O)*Z
00215 NEXT O
00216 NEXT I
00217 N=N+Z
00218 Q =Q+1
00219 M=M+.1
00220 IF N<4 THEN 203
00221 D1=3
00222 P=1
00223 D2=D2+1
00224 FOR O=1 TO D2
00225 C(P)=SQR(C(P))
00226 FOR I=1 TO D2-O+1
00227 C(P+I)= C(P+I)/C(P)
00228 NEXT I
00229 R=P+1
00230 S=R
00231 FOR L=1 TO D2-O
00232 P=P+1
00233 FOR H=1 TO D2+2-O-L
00234 C(R+H-1)=C(R+H-1)-C(P)*C(P+H-1)
00235 NEXT H
00236 R=R+H-1
00237 NEXT L
00238 P=S
00239 NEXT O
00240 T=(D2+1)*(D2+2)/2
```

```
00241 FOR I=1 TO C2-1
00242 T=T-1-I
00243 C(T)=1/C(T)
00244 FOR O=1 TO C2-I
00245 P=D2+1-I-O
00246 P=P*(D2+1-(P-1)/2)-I
00247 R=P-O
00248 S=0
00249 U=I+O+1
00250 V=P
00251 FOR K=1 TO C
00252 V=V+U-K
00253 S=S-C(R+K)*C(V)
00254 NEXT K
00255 C(P)=S/C(R)
00256 NEXT O
00257 NEXT I
00258 C(1)=1/C(1)
00259 T=0
00260 FOR I=1 TO C1+1
00261 B(I)=0
00262 FOR O=1 TO C1-I+2
00263 R=(I+O-1)*(D2+2-.5*(I+O))
00264 B(I)=B(I)+C(T+O)*C(R)
00265 NEXT O
00266 T=I*(D2+(3-I)/2)
00267 NEXT I
00268 RETURN
00269 BDC(1)= MER*23+TER*12+AM*7+DP*17+PY*5
00270 BDC(2)=MER*24+TER*14+AM*7.5+DP*17.5+PY*5
00271 BDC(3)=MER*29+TER*23+AM*10.5+DP*22.5+PY*9
00272 BDC(4)=MER*40+TER*37.5+AM*16.5+DP*52+PY*13
00273 GOSUB 192
00274 DR=B(1)+B(2)*W+B(3)*W**2+B(4)*W**3
00275 IF W<.6 THEN DR=DR-((.6-W)*DR)
00276 PRINT 'DR=',DR,'AT M=',W
00277 M=W
00278 RETURN
00279 DIM GF(2),GP(2),GU(2),AL(2),CG(2),CI(2)
00280 PRINT 'LOW LEVEL SEGMENT'
00281 GOSUB 658
00282 IF I=1 THEN 145
00283 PRINT 'ENTER THE DISTANCE IN NM OF THIS LOW LEVEL LEG :'
00284 INPUT NM
00285 PRINT 'ENTER THE ALT IN FT ABOVE MSL OF THIS LEG (200 FT AS 200):'
00286 INPUT ALT
00287 ALT=ALT/1000
00288 PRINT 'ENTER THE TAS OF THIS LEG (360 KTS AS 360):'
```

```
00289 INPUT TV
00290 PRINT 'ENTER THE OUTSIDE AIR TEMP ( CENT ) AT YOUR ALT:'
00291 INPUT T
00292 M=TV/((38.96)*(T+273)**.5)
00293 PRINT 'YOUR LOW LEVEL MACH=',.01*INT(100*M)
00294 GOSUB 173
00295 WW=GW
00296 WG=GAS
00297 FOR Q= 1 TO 2
00298 M1=.38813+.0042981*(.001*GW)
00299 GOSUB 381
00300 I=0
00301 GOSUB 374
00302 S2=S
00303 IF S1>S2 THEN 306
00304 S=S2
00305 GO TO 325
00306 I=1
00307 GOSUB 374
00308 S3=S
00309 IF S1<S3 THEN 314
00310 S2=S3
00311 I=I+1
00312 GOSUB 374
00313 GO TO 308
00314 I1=(S1-S2)/(S3-S2)
00315 M1=M
00316 I=I-1+I1
00317 I=INT(I)
00318 GOSUB 374
00319 S2=S
00320 I=I+1
00321 GOSUB 374
00322 S3=S
00323 S=S2+(I1*(S3-S2))
00324 GO TO 325
00325 R=S+2*(4.3732E-03+.027743*DR)*M**2
00326 R3=R
00327 R1=2*INT(R/2)
00328 R2=R1+2
00329 J=1
00330 IF J=2 THEN 333
00331 R=R1
00332 GO TO 334
00333 R=R2
00334 B0=5.6253-1.989*R+3.0252*R**2-1.0761*R**3+.17675*R**4
00335 B0=B0-.013095*R**5+3.526E-04*R**6
00336 B1=205.3012-248.9317*R+91.66355*R**2-15.55218*R**3+1.224432*R**4
```

```
00337 B1=B1-.0395333*R**5+2.896385E-04*R**6
00338 B2=-1052.123+1231.24*R-487.4233*R**2+91.6522*R**3-8.662962*R**4
00339 B2=B2+.3953974*R**5-.0069055*R**6
00340 B3=1680.142-1950.139*R+788.8513*R**2-152.5733*R**3+15.03819*R**4
00341 B3=B3-.727414*R**5+.013707*R**6
00342 B4=-864.6875+1000.443*R-408.7451*R**2+80.08314*R**3-8.03958*R**4
00343 B4=B4+.3982527*R**5-7.720617E-03*R**6
00344 N=B0+B1*M+B2*M**2+B3*M**3+B4*M**4
00345 IF J=2 THEN 350
00346 N1=N
00347 J=2
00348 GO TO 333
00349 R=2
00350 N2=N
00351 N=N1+(N2-N1)*(R3-R1)/2
00352 P=4.89*N+7.9E-06*N**2
00353 N4=(6.4375+.010426*T-6.8925E-06*T**2+4.9127E-07*T**3)*M
00354 F=(.1*N4*P)*1000
00355 F=INT(F)
00356 GU=P*NM
00357 GP(Q)=P
00358 GU(Q)=GL
00359 GF(Q)=F
00360 GW=GW-GL
00361 NEXT Q
00362 GU=(GU(1)+GL(2))/2
00363 F=(GF(1)+GF(2))/2
00364 P=(GP(1)+GP(2))/2
00365 GW=WW-GL
00366 GAS = WG-GU
00367 PRINT
00368 PRINT 'THE FUEL USED ON THIS LEG WAS',INT(GL),'LBS.'
00369 PRINT 'YOUR END-OF-LEG FUEL STATE IS',INT(GAS)
00370 PRINT 'YOUR UPDATED GROSS WT IS',INT(GW)
00371 PRINT 'YOUR AVERAGE FUEL FLOW THIS LEG WAS',INT(F),'LBS/HR.'
00372 GO TO 663
00373 PRINT
00374 B0=22.819-31.734*I+41.33*I**2-5.0953*I**3
00375 B1=-154.98+217.51*I-261.73*I**2+35.905*I**3
00376 B2=405.08-525.56*I+607.49*I**2-88.737*I**3
00377 B3=-445.62+542.98*I-611.55*I**2+92.894*I**3
00378 B4=184.78-204.42*I+225.89*I**2-35.189*I**3
00379 S=B0+B1*M1+B2*M1**2+B3*M1**3+B4*M1**4
00380 RETURN
00381 A0=-2.3287-.26316*DR+.0073327*DR**2-7.513E-05*DR**3+3.5396E-07*DR**4
00382 A0=A0-7.78E-10*DR**5+6.4624E-13*DR**6
00383 A1=4.835+1.0956*DR-.030653*DR**2+3.1912E-04*DR**3-1.5276E-06*DR**4
00384 A1=A1+3.408E-09*DR**5-2.8692E-12*DR**6
```

```
00385 A2=10.284-1.0719*DR+.031094*DR**2-3.2878E-04*DR**3+1.595E-06*DR**4
00386 A2=A2-3.6009E-09*DR**5+3.0634E-12*DR**6
00387 S1=A0+A1*M1+A2*M1**2
00388 RETURN
00389 PRINT 'CLIMB SEGMENT'
00390 GOSUB 658
00391 IF I=1 THEN 145
00392 PRINT ' THE A-7E BEST ENERGY CLIMB IS A'
00393 PRINT 'CONSTANT CALIBRATED AIRSPEED CLIMB TO 20000 FT THEN A CONSTANT'
00394 PRINT 'MACH CLIMB ABOVE 20000 FT. FOR YOUR CURRENT FLIGHT CONDITIONS'
00395 PRINT 'THIS SEGMENT WILL GIVE RECOMMENDED CLIMB SPEEDS. DEVIATION'
00396 PRINT 'FROM THESE SPEEDS WILL RESULT IN A SMALL ( 5-7% ) FUEL PENALTY.'
00397 PRINT
00398 PRINT 'ENTER THE START CLIMB ALT ( ENTER 5000 FT AS 5000 ):'
00399 INPUT AL1
00400 AL(1)=AL1/1000
00401 ALT=AL(1)
00402 PRINT
00403 M=.6
00404 FOR E=1 TO 4
00405 GOSUB 173
00406 PP(E)=CF
00407 M=M+.1
00408 NEXT E
00409 FOR I= 1 TO 4
00410 BDC(I)=PP(I)
00411 NEXT I
00412 GOSUB 192
00413 M=.3
00414 CD1=B(1)+B(2)*M+B(3)*M**2+B(4)*M**3
00415 CD2=7846.4313-31915.4533*M+44780.4062*M**2-21243.9031*M**3
00416 IF ABS(CD1-CD2)<5 THEN 419
00417 M=M+.005
00418 GO TO 414
00419 CAS=404.5-.78*CD1+.001*CD1**2
00420 PRINT
00421 PRINT 'RECOMMENDED CLIMB SPEED IS',INT(CAS),'KTS CAS TO 20000 FT'
00422 PRINT 'THEN',INT(M*100)*.01,'MACH ABOVE 20000 FT.'
00423 GOSUB 173
00424 GS=GW/1000
00425 B1=-2.7877+.025635*DR-3.3063E-04*DR**2+1.4162E-06*DR**3
00426 B1=B1-1.8343E-09*DR**4
00427 B2=.063327-8.5289E-04*DR+1.0814E-05*DR**2-4.6514E-08*DR**3
00428 B2=B2+6.0606E-11*DR**4
00429 B3=-6.0468E-04+9.0826E-06*DR-1.143E-07*DR**2+4.9304E-10*DR**3
00430 B3=B3-6.4567E-13*DR**4
00431 B0=85.118-.29117*DR+.0030434*DR**2-1.2851E-05*DR**3
00432 B0=B0+1.6621E-08*DR**4
```

```
00433 L=B0+B1*GS+B2*GS**2+B3*GS**3
00434 IF L>39 THEN L=39
00435 PRINT 'THE ALT FOR MAX CRUISE RANGE FOR YOUR CONFIGURATION IS'
00436 PRINT INT(L*1000),'FT.'
00437 B1=55.333+.073076*DR-9.7836E-04*DR**2+3.5015E-06*DR**3
00438 B1=B1-3.9782E-09*DR**4
00439 B2=-1.1-8.0597E-03*DR+8.0097E-05*DR**2-2.8836E-07*DR**3
00440 B2=B2+3.3032E-10*DR**4
00441 B3=6.6667E-03+1.2541E-04*DR-1.4039E-06*DR**2+5.2032E-09*DR**3
00442 B3=B3-6.0218E-12*DR**4
00443 L=B1+B2*GS+B3*GS**2
00444 PRINT 'MAX ENDURANCE ALT FOR YOUR CONFIGURATION IS'
00445 PRINT INT(L*1000),'FT.'
00446 PRINT
00447 PRINT 'ENTER THE ALT YOU ARE CLIMBING TO (30000 FT AS 30000):'
00448 INPUT AL2
00449 AL(2)=AL2/1000
00450 FOR J= 1 TO 2
00451 ALT=AL(J)
00452 GOSUB 173
00453 GWS=GW/1000
00454 RN=(.0125+.0208*ALT+.00006*ALT**2)*(GWS-3)
00455 IF ALT > 26. THEN 456 ELSE 457
00456 RN=RN-.3
00457 IF (ALT <24 AND ALT>12 ) THEN 458 ELSE 459
00458 RN=RN+.15
00459 IF ALT<9 THEN 460 ELSE 461
00460 RN=RN-.15
00461 GC=(199.4643+1.2932*DR-.0009*DR**2)*RN
00462 IF ((GC-(.7*DR)<0)) THEN 466
00463 IF ((DR>49)AND(RN<3.8)) THEN GC=GC-(.7*DR)
00464 IF GC<(.7*DR) THEN GC = (300*RN)
00465 IF ((DR>180) AND (RN>2.5)) THEN GC=GC+(30*RN)
00466 IF AL(J)<1 THEN GC=0
00467 RN=(.0026+.0006*ALT+.0001*ALT**2)*(GWS-5)
00468 IF ALT>13 THEN RN=(RN-(.000029*ALT**2*GWS))
00469 IF (ALT>10 AND ALT<25 ) THEN RN=(RN+.1)
00470 DIS=(20.1298+.1451*DR-.0005*DR**2)*RN
00471 IF DR>100 AND RN>.9 THEN 472 ELSE 473
00472 DIS=DIS+((.0011*(DR-100)**2*RN)-(1-RN/2)*(DR/6))
00473 IF DR>50 AND RN>1.8 THEN 474 ELSE 475
00474 DIS=DIS-((DR-50)*(1.8-.95*RN))
00475 DI(J)=DIS
00476 CG(J)=GC
00477 NEXT J
00478 IF ((AL(1)+1)>AL(2)) THEN DI(1)=0
00479 DIS=DIS-DI(1)
00480 GC=GC-CG(1)
```

```
00481 PRINT 'GAS AND DIS FROM',AL(1)*1000,'TO',AL(2)*1000,'IS'
00482 PRINT INT(GC),'LBS AND',INT(DIS),'NM'
00483 GW=GW-GC
00484 GAS=GAS-GC
00485 PRINT
00486 PRINT 'UPDATED FUEL AFTER THE CLIMB IS',INT(GAS),'LBS.'
00487 PRINT 'UPDATED GROSS WEIGHT IS',INT(GW),'LBS.'
00488 GU=GC
00489 PRINT
00490 GO TO 663
00491 PRINT 'CRUISE LEG'
00492 GOSUB 658
00493 IF I=1 THEN 145
00494 PRINT 'ENTER YOUR CRUISE MACH:'
00495 INPUT M
00496 PRINT 'ENTER YOUR CRUISE ALT (30000 FT AS 30000):'
00497 INPUT ALT
00498 ALT=ALT/1000
00499 GOSUB 173
00500 PRINT 'ENTER THE TEMP IN C AT YOUR NEW ALT ( 15 DEG AS 15):'
00501 INPUT T
00502 TV=38.96*(T+273)**.5*M
00503 PRINT 'YOUR TAS IN KTS IS',INT(TV)
00504 DE=.9991-.0354*ALT+.0005*ALT**2
00505 SP=661.5*(DE**.5)*M
00506 IF PS=3 THEN 508
00507 PRINT 'YOUR CAS IN KTS IS',INT(SP)
00508 TS=2.155-9.95*M+22.5*M**2
00509 N=(.4415+.0238*DR+.0001*DR**2)*(M-.3)
00510 IF DR<50 OR M<.4 THEN 512 ELSE 511
00511 N=N-(DR-50)**2*.00013*(M-.4)
00512 RN=2*N+19
00513 N=(8.1-22.5167*M+22.75*M**2-8.3333*M**3)+(1+.3*(RN-2))
00514 IF M<.6 THEN N=N-(.6*(M-.6)*(RN-8))
00515 IF M>.6 THEN N=N-(.25*(M-.6)*(RN-8))
00516 N=N+.1*(RN-8)
00517 P=(4.9993-.1823*ALT+.0028*ALT**2)*N
00518 F=TV*P
00519 IF F1=99 THEN 530
00520 PRINT 'YOUR FUEL FLOW IS',INT(F),'. YOUR LB/NM IS',INT(P)
00521 PRINT 'ENTER THE DISTANCE OF THIS LEG IN MILES:'
00522 INPUT DI
00523 GU=P*DI
00524 PRINT 'GAS USED THIS LEG=',INT(GU)
00525 GW=GW-GU
00526 GAS =GAS-GU
00527 F1=0
00528 PRINT 'UPDATED GROSS WEIGHT=',INT(GW),'.FUEL LEFT=',INT(GAS)
```

```
00529 GO TO 663
00530 F1=0
00531 RETURN
00532 PRINT 'RENDZ SECTION'
00533 GOSUB 658
00534 IF I=1 THEN 145
00535 F1=99
00536 PRINT 'ENTER RENDEZVOUS ALT (15000 FT AS 15000):'
00537 INPUT ALT
00538 ALT =ALT/1000
00539 PRINT 'ENTER RENDEZVOUS AIRSPEED (CAS,ENTER 250 AS 250):'
00540 INPUT SP
00541 PRINT 'ENTER TIME IN MIN TO RENDEZVOUS AND/OR TANK:'
00542 INPUT MI
00543 PRINT 'ENTER FUEL IN LBS ON/OFF-LOADED FROM/AS TANKER ( 0 FOR NONE) '
00544 PRINT 'ENTER OFFLOAD AS NEGATIVE NUMBER :'
00545 INPUT CX
00546 DE=.9991-.0354*ALT+.0005*ALT**2
00547 M=(1/DE**.5)*SP/661.5
00548 HR=MI/60
00549 GOSUB 173
00550 M=W
00551 GOSUB 500
00552 GU=(HR*F)*1.1
00553 PRINT 'YOUR M=',INT(W*100)*.01
00554 PRINT 'FUEL USED IN RENDZ =',INT(GU),'LBS'
00555 GW=GW-GU+CX
00556 PRINT 'NEW GW =',INT(GW),'LBS'
00557 GAS=GAS-GU+CX
00558 PRINT 'UPDATED FUEL =',INT(GAS),'LBS'
00559 F1=0
00560 GO TO 663
00561 PRINT 'MAX RANGE DESCENT SECTION'
00562 GOSUB 658
00563 IF I=1 THEN 145
00564 GW=GW/1000
00565 M=.4
00566 PRINT 'ENTER THE DESCENT START ALT (20000 FT AS 20000):'
00567 INPUT ALT
00568 ALT=ALT/1000
00569 AL1=ALT
00570 GOSUB 589
00571 F3=F
00572 D3=DIS
00573 SP=(111-.0618*DR+.0004*DR**2)+((4.5471-.0059*DR)*GW)
00574 SP=INT(SP)
00575 PRINT 'THE MAX RANGE DESCENT SPEED IS',SP,'KTS CAS.'
00576 PRINT 'ENTER THE LEVEL-OFF ALT (ENTER 2000 FT AS 2000):'
```

```
00577 INPUT ALT
00578 ALT=ALT/1000
00579 GOSUB 590
00580 DIS=D3-DIS
00581 F=F3-F
00582 PRINT 'DISTANCE AND FUEL TO DESCEND FROM',AL1*1000,'TO'
00583 PRINT ALT*1000,'FT IS',INT(DIS),'MILES AND',INT(F),'LBS.'
00584 GAS=GAS-F
00585 GW=(GW*1000)-F
00586 PRINT 'UPDATED GROSS WEIGHT AND FUEL ARE',INT(GW),'AND',INT(GAS)
00587 GU=F
00588 GO TO 663
00589 GOSUB 173
00590 N=(.4+.1186*ALT+.0017*ALT**2)
00591 N=N+(.0079-.0037*ALT+.0002*ALT**2-.0000033*ALT**3)*GW
00592 IF (ALT<21 AND ALT>8) THEN N=N+.18
00593 DIS=(16.6646-.0705*DR+.00023*DR**2)*N
00594 IF DR>149 THEN 595 ELSE 596
00595 DIS=DIS-((DR-150)*.04*N)
00596 DIS=INT(DIS)
00597 N=.2*(ALT-25)+(14.9-.43*GW+.005*GW**2)
00598 F=(37.4214-.1250*DR+.0004*DR**2-5E-07*DR**3)*N
00599 F=INT(F)
00600 RETURN
00601 PRINT 'ATTACK SECTION'
00602 GOSUB 658
00603 IF I=1 THEN 145
00604 PRINT 'ENTER FUEL IN LBS YOU ESTIMATE TO USE IN THE ATTACK.'
00605 PRINT 'A TYPICAL WEAPONS DELIVERY TACTIC TAKES ABOUT 600 LBS:'
00606 INPUT GU
00607 GAS=GAS-GU
00608 PRINT 'ENTER ORDNANCE WT IN LBS DROPPED ON TARGET:'
00609 INPUT CX
00610 CX=-OX
00611 F2=99
00612 GW=GW+CX-GU
00613 PRINT 'GROSS WT AFTER ATTACK=',INT(GW)
00614 PRINT 'FUEL STATE AFTER ATTACK =',INT(GAS)
00615 GO TO 663
00616 PRINT 'TANK SEGMENT'
00617 GOSUB 658
00618 IF I=1 THEN 145
00619 F1=99
00620 PRINT 'ENTER YOUR TANK ALT IN FT:'
00621 INPUT ALT
00622 ALT=ALT/1000
00623 PRINT 'ENTER YOUR TANK CAS IN KTS:'
00624 INPUT SF
```

```
00625 PRINT 'ENTER YOUR TANK ON(+)/OFF(-) LOAD OF FUEL IN LBS:'
00626 INPUT CX
00627 PRINT 'ENTER TEMP (C) AT YOUR ALT:'
00628 INPUT T
00629 PRINT 'ENTER YOUR TANKING TIME IN MIN:'
00630 INPUT G
00631 M=(1/(.9991-.0354*ALT+.0005*ALT**2)**.5)*SP/661.5
00632 TV=38.96*(T+273)**.5*M
00633 GOSUB 173
00634 GOSUB 508
00635 GU=G/60*F*1.1
00636 DIS=G/60*TV
00637 GAS=GAS-GU+CX
00638 GW=GW-GU+CX
00639 PRINT 'YOUR NEW FUEL STATE IS',INT(GAS),'LBS'
00640 PRINT 'YOUR NEW GROSS WEIGHT IS',INT(GW),'LBS'
00641 PRINT 'DISTANCE TRAVELED THIS LEG=',INT(DIS),'NM.'
00642 GO TO 663
00643 PRINT 'END OF MISSION SEGMENT'
00644 GOSUB 658
00645 IF I=1 THEN 145
00646 PRINT 'YOUR END-OF -MISSION GROSS WT IS',INT(GW)
00647 PRINT 'YOUR FUEL STATE IS',INT(GAS)
00648 IF GAS<0 THEN 649 ELSE 654
00649 GAS=ABS(GAS)
00650 PRINT 'YOU HAVE A NEGATIVE FUEL STATE WHICH MEANS YOU NEED'
00651 PRINT 'AT LEAST',INT(GAS),'MORE LBS FUEL FOR THIS PROFILE PLUS'
00652 PRINT 'A RESERVE. YOU MUST TANK, CHANGE YOUR PROFILE, OR'
00653 PRINT 'TAKE-OFF WITH MORE FUEL.'
00654 PRINT 'TO START ALL OVER AGAIN, TYPE IN A 1 (ONE); ELSE, PRESS ENTER.'
00655 ON CONV GOTO 672
00656 INPUT N
00657 IF N=1 THEN 5
00658 I=0
00659 PRINT 'TO CONTINUE, PRESS ENTER. TO RETURN TO MISSION MENU, ENTER A 1.'
00660 ON CONV GOTO 662
00661 INPUT I
00662 RETURN
00663 PRINT 'IF YOU WISH TO REDO THIS PART FROM THE BEGINNING WITH NEW INPUTS,'
00664 PRINT 'ENTER A 1, ELSE JUST PRESS ENTER TO CONTINUE.'
00665 ON CONV GOTO 145
00666 INPUT I
00667 GW=GW+GU-CX
00668 GAS=GAS+GU-CX
00669 IF PS=6 THEN F2=0
00670 IF PS=6 THEN GAS=GAS+CX
00671 GO TO 162
00672 END
```

LIST OF REFERENCES

1. A-7E Naval Air Training Operational Procedures and Standardization Manual, NAVAIR 01-45AEE-1, 1 December 1979.

2. Siegel, W. M., Computerization of Tactical Aircraft Performance Data for Fleet Application, M. S. Thesis, Naval Postgraduate School, Monterey, CA. June 1978.

3. Koger, G. L., The Development and Implementation of Algorithms for an A-7E Performance Calculator, M.S. Thesis, Naval Postgraduate School, Monterey, CA. September 1978.

4. Wylie, C. R., Advanced Engineering Mathmatics, 4th ED., p. 153-170, McGraw-Hill, 1975.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, Virgina 22314	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93943	2
3.	Department Chairman, Code 67 Department of Aeronautics Naval Postgraduate School Monterey, California 93943	1
4.	Professor D. M. Layton, Code 67Ln Department of Aeronautics Naval Postgraduate School Monterey, California 93943	1
5.	Commander R. D. Hill, Code 35 Commander Light Attack Wing Pacific NAS Lemoore, California 93245	2
6.	Commander Light Attack Wing One, Code 30 NAS Cecil Field, Florida 32210	1
7.	Commander Naval Air Rework Facility A-7 Weapons Systems Manager NAS Jacksonville, Florida 32205	1

210253

Thesis
H53321 Hill
c.1 The development of a
performance and mission
planning program for
the A-7E aircraft.